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TECHNOLOGY ON THE BATTLEFIELD

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It is an old adage that “generals always fight the last war.” That is often because defense establishments are often the last to acknowledge the disruption that is changing the battlefield and the very nature of warfare.

To make certain that Western defense establishments are prepared for the next conflict, it’s important to recognize that the battlefield of today and tomorrow is not the one of yesteryear – and that yesterday’s means of warfare are always the first casualty of today’s technology breakthroughs and innovations.

Three major trends are shaping warfare: an asymmetric battlefield, ever-escalating costs of modern weaponry, and maintaining deterrence in an environment of a growing arms race. Nations are struggling to address these trends:

- Given the dispersed and asymmetric nature of the battlefield, there is a greater need for adaptable, stealth, and resilient combat capabilities.
- Costs of personnel and development of traditional manned combat platforms are rising rapidly; the cost of the US intervention in Iraq reached $4.6 trillion, which is higher than the $3.6 trillion spent overall to fight World War II (after adjusting for inflation).
- Global deterrence strategy remains at the top of nations’ agendas, given the arms race taking place at NATO’s borders.

Currently, disruptive technologies attempting to tackle these trends are clustered in two areas:

- Technologies that enhance warfare effectiveness, offering a greater reach of targets at a lower cost and rate of fatalities.
- Technologies supporting national/supranational-scale defense efforts to remain in the arm race and maintain deterrence.

We’ll look at the technologies that make up the two clusters and show how warfare is facing continuing disruption.

COLLABORATIVE COMBAT WITH TECHNOLOGY

The increasing dispersed and asymmetric nature of the enemy in tandem with growing cost pressures has triggered the need for more effective weaponry. As a result, a key priority of the defense establishment in the West is to do more with less – operating with smaller budgets and lowering the number of fatalities. We have identified six key technologies capable of delivering on this promise.

UNIFIED BATTLEFIELD: COLLABORATIVE COMBAT

The modern-day unified battlefield is characterized by collaborative combat in which there is uninterrupted land-air-sea real-time sharing of battlefield information by multiple participants (manned and unmanned vehicles, ground forces, naval assets, remote operations).

This unified battlefield is supported by the development of four key innovations: the growing "softwarization" of combat – the F-35 fighter jet, for example, has more than 8 million lines of code, four times the number that was in the F-22 Raptor; the extension of secured communications via high-frequency satellites, laser and free space optical communications, and a new generation of small, low-cost receiving terminals; the huge amounts of data due to the development of high-speed computers, improved performance of sensors, tactical decision aids and weapons; and effective deployment of tactical cloud computing, integrating vast amounts of data in real-time and distributing it to multiple users rapidly.

Unified, collaborative combat significantly increases force effectiveness by rapidly exploiting all-source intelligence, delivering timely information to commanders in the field, distributing tactical photos, synchronizing day/night operations under all weather conditions, and preventing casualties through friendly fire.

For example, the new tanks' interconnection systems, developed by leading suppliers of defense electronic systems, enable tanks to operate alongside wheeled armored vehicles equipped with common vetronics, in order to collect and transform battlefield sensor data into high-value protection and combat services. These collaborative capabilities support C4I applications (Command, Control, Computers, Communications, and Intelligence), providing commanders with information superiority and significantly raising the tempo of operations.

ARTIFICIAL INTELLIGENCE INCREASES TARGET REACH AND REQUIRES LESS MANPOWER

Artificial intelligence will be deployed all across the battlefield to accelerate decision-making. Other applications for AI include cyber security, target recognition, battlefield healthcare, or combat simulation and training. The size of the market for AI in the military is expected to reach $19 billion by 2025, increasing at a compound annual growth rate of nearly 15 percent from 2017 to 2025. In September 2018, the US Defense Advanced Research Public Agency (DARPA) announced a multi-year investment of more than $2 billion in the "AI Next" campaign, consisting of new and existing AI programs.

Artificial intelligence enables greater target reach, as intelligent systems possess augmented precision capabilities and a shorter reaction time. Plus, by moving away from the battlefield, personnel are able to stay out of harm's way, while orchestrating a larger number of unmanned systems at a lower cost.

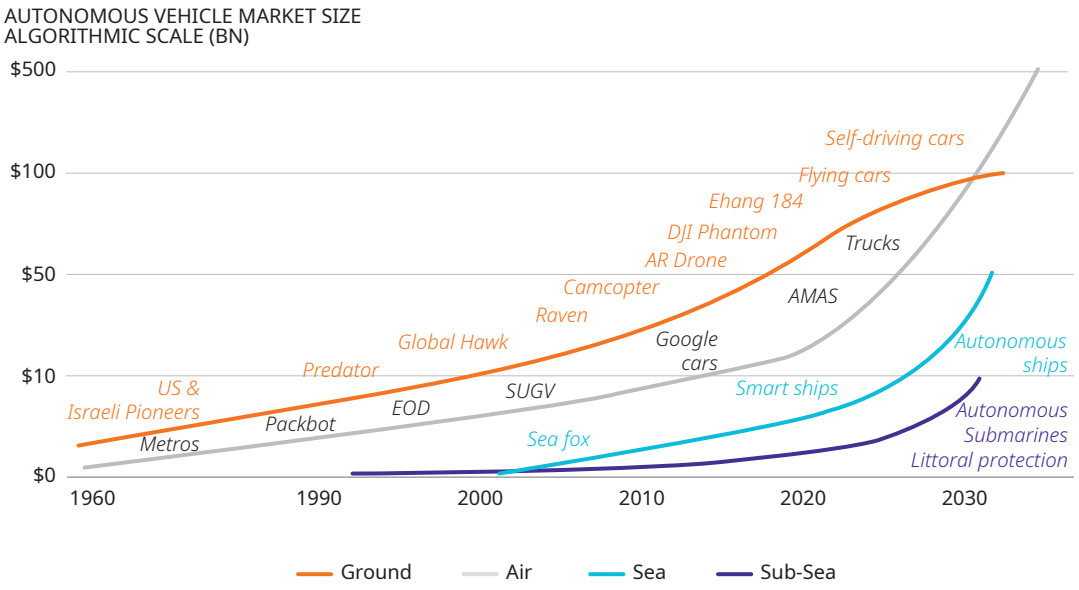
For instance, the Air Combat Evolution (ACE) program created by DARPA in 2019 uses human-machine collaborative dogfighting to prove the efficiency of autonomous combat technology. This technology will achieve greater efficiency as it elevates the role of pilots to cockpit-based mission commanders, keeping them safer and enabling them to pilot more unmanned aircraft as "loyal wingmen" that can penetrate contested air space.

However, even as intelligent machines perform more and more missions on their own, human insight will always be necessary to understand and evaluate the broader context and step outside the frame before making any lethal call.

AUTONOMY PAVES THE WAY TO GREATER NUMBERS OF SMALLER ARMED CARRIERS

Boosted by the recent developments in sensors, advanced computing and processing power, autonomy touches all types of platforms, with different levels of maturity. Acceleration of autonomy is expected within the next 10 years, especially for sea and ground vehicles (See Exhibit 1).

Exhibit 1. Expect an outstanding acceleration within the next 10 years…



Source: Oliver Wyman analysis

Currently, the most significant application of autonomy in the military domain is unmanned aerial systems (UAS), capable of performing autonomous takeoff, navigating to predetermined waypoints, and landing. The market size for military unmanned aerial systems was $6.8 billion in 2015 and is expected to reach $11.9 billion in 2025, growing at a 4 percent compounded annual growth rate.

Unmanned aerial systems can operate individually but can also be launched collectively as "swarm attacks." A swarm is a network of cooperative and connected unmanned systems which engage targets collectively to overwhelm the enemy. Combined with artificial intelligence, swarms could autonomously jam, deceive, and employ nonlethal disruptive weapons. Many armed forces have already taken the step: in February 2019, the UK Defense Secretary announced the deployment of swarm squadrons by 2020.

Autonomy—especially its application in unmanned aerial systems – is a key step toward reducing the cost of warfare. Indeed, both procurement and operational costs of unmanned systems are significantly lower than manned systems. For example, the hourly operational cost of the F-22 is $68,362, as compared with the Predator's $3,679. Exhibit 2 shows an assessment of the cost differentials between UAS families and manned carriers.

Exhibit 2. Unnamed costs as share of manned costs

Type of UAV	Cost per flight hour	Procurement cost
Light tactical	6%	8%
MALE	17%	22%
HALE	47%	70%

Source: Oliver Wyman analysis

Furthermore, the ability to multiply the number of low-cost unmanned aerial vehicles in "swarms" will enable favorable cost-exchange ratios, as armed forces will build large numbers of low-cost expendable agents with shorter reaction times than humans. This is key in reversing the trend of rising aircraft costs and reducing quantities.

ADDITIVE MANUFACTURING, FASTER PRODUCTION CYCLES, AND LOWER MAINTENANCE COSTS

3D-printing has been identified by major armed forces as a key enabling technology and is already operational. For instance, Naval Air Systems Command (NAVAIR) recently stated that its fleet relies on the use of 1,000 3D-printed parts.

Additive manufacturing improves warfare effectiveness in three key dimensions: tools and parts production, maintenance, and logistical support for deployment in remote and hostile environments. Exhibit 3 shows the impact on each of these dimensions and initial examples of applications.

Exhibit 3. Examples of additive manufacturing impacts

	Impact on effectiveness	Example
Production of tools and parts	• Production cost reduction • Rapid prototyping of new systems/rapid scaling up of production • Weight reduction and increase in component resistance and durability	Printed metal-alloy nozzles for the LEAP engine have about 5x more durability and weigh 25% less
Maintenance	• Higher operational readiness and sortie rates • Lower transportation costs • Greater process predictability • Reduced lead times • Efficiency in inventory and waste	U.S. Air Force maintainers installed a 3D-printed titanium bracket on an F-22 Raptor -- the first operational use of a metallic 3D-printed part on an F-22
Logistical support for deployed forces	• Printing replacement parts for key battlefield equipment at lower costs • Reduced dependency on long-range logistics infrastructure	US Army decade-old Mobile Parts Hospital

Source: Oliver Wyman analysis

THE HUMAN WAR MACHINE: A NEW FRONTIER OF INFANTRY

Collaboration between humans and machine will enable unprecedented capabilities from the warfighter, improving target reach at lower fatality rates. Infantrymen fitted with integrated-powered exoskeletons could transform foot soldiers into genuine super-fighters.

The reach of an "augmented soldier" is multiplied. Exhibit 4 shows the main expected benefits, either through increased protection or through augmented capabilities**.**

Exhibit 4. Examples of benefits expected from augmented soldier

Impact of technology	Illustrative examples
Increased protection	• US Army & US Special Operations Command invested $81 million into developing a Tactical Assault Might Operator Suit (TALOS) that integrates advanced armor, command and control computers, power generators, and enhanced mobility skeletons
Augmented capabilities	• DARPA is developing new wirelessly connected lightweight lens providing augmented vision assistance, with continuous supply of light source (LED) for several hours • Malleable fabric exosuits, whose purpose is to make soldiers more agile and less fatigued

Source: Oliver Wyman analysis

ELECTRIC WEAPONS: HIGHER FIRING RATES AT LOWER COST PER SHOT

The military has grown reliant on precision-guided munitions (PGMs) to execute military operations. PGMs are used in ground, air, and naval operations, and include air- and ship-launched missiles, multiple launched rockets, and guided bombs. Currently, these guided munitions have become offensively dominant, leaving defenders at a disadvantage in addressing the challenges presented by PGMs. For example, spending $10 million to $15 million on interceptors against a single missile is unsustainable, especially when defending against future UAS swarm attacks.

Therefore, electric weapons – high-energy lasers, electromagnetic rail guns – are being considered for their high rates of fire and low cost per shot, which could substantially improve the ability of Navy surface ships to defend themselves against surface craft, unmanned aerial vehicles (UAVs), and eventually anti-ship cruise missiles (ASCMs).

- Precision strikes that can counter even the most advanced area defense systems to air defense against incoming targets
- No need to store the hazardous high explosives and flammable materials necessary to launch conventional projectiles
- Greater degree of autonomy and unmanned systems

In January 2019, The US Office of Naval Research demonstrated the first Navy's electromagnetic railgun. Relying on massive electrical pulse, rather than gunpowder or other chemical propellants, it can launch projectiles at distances over 100 nautical miles – at speeds exceeding Mach 6.

RESEARCH EFFORTS NEEDED TO MAINTAIN DETERRENCE

China, Russia, and the US are investing massively in future weapons and types of warfare, which while unlikely to be used, are necessary for maintaining deterrence and the balance of power.

THREE KEY TECHNOLOGIES OF THE NEW ARMS RACE

Cyber warfare, hypersonic weapons, and space warfare are the three key technologies of the new arms race. Read below in more detail why that is.

- Cyber warfare is the use of computer technology to disrupt the activities of a state or an organization. Cyberattacks have been increasing dramatically, with increasingly high impact on costs for hacked organizations. NATO officially reported 500 cyber incidents a month, increase of 60 percent over 2015 (Source: NATO). With the rise of adjacent technologies such as the Internet-of-Things (IoT) and artificial intelligence, cyberspace will be the future battlefield for warfare.
  - With the development of the IoT – there will be an estimated 200 billion connected devices by 2020 – and its "colonization" of physical space, more and more systems will be linked together and susceptible to manipulation
  - Artificial intelligence will be used as weaponry through "autonomous cyber attacks": once released, these self-learning attacks will no longer be controlled
- A hypersonic weapon is a missile that travels at least five times faster than the speed of sound. Given this speed, such missiles are virtually impossible to avoid, identify, or neutralize. There are two types of hypersonic weapons:
  - Hypersonic cruise missiles: Capable of achieving altitudes of up to 100,000 feet, powered to their targets using an advanced propulsion system called a SCRAMJET
  - Hypersonic glide vehicles: Capable of achieving altitudes greater than 100,000 feet, uses aerodynamic forces to maintain stability and to maneuver
- Space warfare refers to the development of capabilities to threaten the ability of the enemy to use space. It includes satellite-related warfare, such as attacking satellites from Earth (ground-to-space warfare), or satellites attacking satellites (space-to-space warfare)

CHINA HAS TAKEN A CLEAR LEAD ON THE ARM RACE, FOLLOWED BY RUSSIA AND THE US

China has taken significant steps to lead in both hypersonic and space warfare and is arguably leading the hypersonic weapons race. In November 2017, China flew a new hypersonic missile, the DF-17, capable of flying 1,800 to 2,500 kilometers. Furthermore, they presented a total of 260 papers at the 2017 AIAA International Space Planes and Hypersonic Systems and Technologies Conference (more than all other countries combined).

Exhibit 5. Papers presened at AIAA International Space Planes and Hypersonics Systems and Technology Conferences

Papers presented annually per country - 2005 to 2017

Country[1]	2005	2006	2008	2009	2011	2012	2014	2015	2017	Total
China	7	17	4	15	18	31	3	42	260	397
US	61	64	38	38	60	15	18	32	14	340
Germany	11	17	16	30	28	25	10	18	9	164
France	22	13	13	16	16	15	5	18	8	126
Australia	8	24	7	20	10	26	8	13	7	123
Japan	21	17	16	14	13	20	4	7	1	113
Italy	27	10	7	19	16	8	0	7	5	99
European Groups	6	6	6	8	9	5	1	8	6	55
Russia	14	5	6	4	3	6	0	5	5	48
UK	2	5	0	6	3	4	1	13	4	38
Total	**179**	**178**	**113**	**170**	**176**	**155**	**50**	**163**	**319**	**1,503**

1. Other nations presenting paper at the 2017 conference were Algeria, Belgium, Brazil, Canada, Greece, Hungary, India, Iran, Netherlands, Norway, Saudi Arabia, Singapore, South Korea, Sppain, Sweden, Switzerland, Taiwan and Turkey;
2. European Organizations

Source: IDA Sciences and Technology Policy Institute

Furthermore, China is also gaining an advantage in space warfare. As stated in their Space White Paper from December 2016: “To explore the vast cosmos, develop the space industry, and build China into a space power is a dream we pursue unremittingly.” In January 2019, China became the first country to land a probe on the far side of the moon. Neither Russia nor the United States has pursued this technical achievement. China’s government announced the development of a ground-based laser that can blind optical sensors on satellites in low-Earth orbit, a weapon that should be operational by 2020. Finally, unlike the United States or Russia, China is also believed to have the capacity to use missiles to attack satellites in the more distant geosynchronous orbit (35,800km above Earth).

Russia is fast on the heels of China in space warfare, with a clear focus on directed energy weapons (such as lasers or high-powered microwaves) that can disable targets in space. However, there are some serious doubts on Moscow's hypersonic claims, such as the flight of the Sarmat, a 200-ton ballistic missile with multiple hypersonic warheads in December 2017. Indeed, Russia has had setbacks, due to difficulties with technology and scarce resources. For example, in 2017 Russia's space program launched the fewest number of rockets since 1965—and of those rockets launched many were for US missions.

The United States is investing massively in hypersonic weapons and space warfare to keep up with China. On hypersonic weapons, the US Dept. of Defense awarded Lockheed Martin a $928 million contract to develop and test the Hypersonic Conventional Strike Weapon in April 2018.

Regarding space warfare, the US Space Force aspires to pull together the all Defense Department's space experts under one umbrella to build expertise. The key objectives of this new branch would be to speed up space acquisition, enabling new technology to be fielded faster.

EUROPE IS STARTING TO JOIN FORCES ON CYBERSECURITY

A common defense strategy is shaping up at the European Union level. The Directive on security of network and information systems - NIS Directive - adopted by the European Parliament in 2016 is the first piece of EU legislation on cybersecurity. This directive is aimed at achieving a high level of network and information security to scale up capabilities, cooperation, and risk management practices across EU member states.

Additionally, the European Commission and High Representative presented in 2017 a wide range of measures to strengthen cybersecurity in the EU. Among them:

- Establishment of an EU-wide cybersecurity certification scheme for products, processes and services
- Creation of a European Cybersecurity Research, Industrial and Technological Competence Centre to develop and deploy the tools and technologies necessary to adapt to the evolving cyberattacks
- €2 billion invested in the EU's cybersecurity sector under the Digital Europe Program

CONCLUSION

The legacy defense industrial base recognizes the need to integrate two overarching dynamics in their core strategy: Novel technologies, supporting greater warfare effectiveness on the one hand, and supranational advanced weaponry on the other. In concrete terms, contractors ought to coherently choose where and how to compete. In doing so, they can consider several viable strategies. For one, they can maintain their legacy role as pureplay manufacturers and integrators of complex weapons platforms, with the hope that renewed focus on peer adversaries will drive more platform spending by domestic and export defense markets. Second, they can expand into adjacent segments that are peripheral to their primary markets and product lines. Third, legacy players can broader their value proposition by enabling differentiated customer solutions with digital technology capabilities such as artificial intelligence and machine learning to reduce sustainment costs. This would include value-added solutions such as digital maintenance, inventory management of spare parts, remote virtual training, and enhanced mission preparation. This would require, however, building expertise in non-core competencies such as data platform architecture, advanced data analytics, and statistical modeling skills traditionally viewed as the domain of commercial technology companies.

Implementing one of these options, legacy players benefit from a key advantage, as current market leaders, and having direct access to customers and end-users. On the downside, however, they have limited track records leading disruption within their markets, let alone transforming themselves internally. To position for the future, by growing innovation capabilities and creating disruptive value propositions, legacy defense players will need to turn greater attention to four areas:

- Partnerships –leverage partnerships developed with commercial technology firms, scouting and ingesting their technologies and assimilating aspects from their cutting-edge ethos
- Talents – hire, train and retain talent with an expansive skillset, to support technology advances in an information-centric era (AI, analytics, cloud, dev/ops, etc.)
- Internal innovation and R&D processes – strengthen their own R&D efforts by putting end-users at the center of innovation, foster open innovation, and adapt development processes to foster dev/ops.
- Tech investments –assume more risk in making investments in technology they believe military customers will adopt: instead of waiting for customers to define requirements, make calculated bets on what is next – or else, cede what was once considered the rightful domain of legacy players to commercial tech competitors

Traditional defense industry players need to pick their own battles and equip themselves with the necessary capabilities and behaviors to undergo and lead the technology disruption that is shaping how customers fight future conflicts. This will enable them to remain relevant through the delivery of more effective warfighting capabilities as nations' defense strategies evolve.

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